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(54) NOVEL GUANOSINE TRIPHOSPHATE (GTP)-BINDING PROTEIN CONJUGATE TYPE RECEPTOR PROTEINS

(57) The present invention provides a full-length cDNA encoding a rat G protein-coupled receptor protein, which was isolated by screening cDNA libraries originating from rat thalamus and hypothalamus. It also provides human cDNA corresponding to the rat cDNA. Use of these G protein-coupled receptor proteins makes it possible to screen ligands and also drug-candidate compounds capable of regulating signal transduction from receptors.

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Description

Technical Field

[0001] The present invention relates to a novel guanosine triphosphate binding protein-coupled receptor protein, a DNA encoding said protein, and a method for screening drug-candidate compounds using them.

Background Art

[0002] Many hormones and neurotransmitters regulate physiological functions through specific receptor proteins located on the cell membrane. Many of these receptor-proteins transduce signals into the cell by activating a guanosine triphosphate binding protein (occasionally referred to as "G protein" below) that is coupled to them. These receptor proteins are thereby named as G protein-coupled receptors. Since they have a common structure composed of seven transmembrane regions, they are also generally called "seven-transmembrane receptor proteins."

[0003] G protein-coupled receptors, which are expressed on the surface of cells *in vivo* and functioning cells of tissues, play an extremely important role as a target of molecules such as hormones, neurotransmitters, and biologically active compounds, which regulate the functions of these cells and tissues. Therefore, G protein-coupled receptor proteins have received great attention as targets in drug-development.

[0004] G protein-coupled receptors reported so far include, muscarinic acetylcholine receptors M1, M2, M3, and M4 (Peralta E.G. et al., EMBO J. 6:3923-3929 (1987)), muscarinic acetylcholine receptor M5 (Bonner T. I. et al., Neuron 1:403-410 (1988)), adenosine receptor A1 (Libert F. et al., Science 244:569-572 (1989)), α1A adrenoreceptor (Bruno J.F. et al., Biochem. Biophys. Res. Commun. 179:1485-1490 (1991)), β1 adrenoreceptor (Frielle T. et al., Proc. Natl. Acad. Sci. USA 84:7920-7924 (1987)), angiotensin receptor AT_1 (Takayanagi R. et al., Biochem. Biophys. Res. Commun. 183:910-916 (1992)), endothelin receptor ET_A (Adachi M. et al., Biochem. Biophys. Res. Commun. 180:1265-1272 (1991)), gonadotropin releasing factor receptor (Kaker S.S. et al., Biochem. Biophys. Res. Commun. 189:289-295 (1992)), histamine receptor H_2 (Ruat M. et al., Proc. Natl. Acad. Sci. USA 87:1658-1672 (1992)), neuropeptide Y receptor Y1 (Larhammar D. et al., J. Biol. Chem. 267:10935-10938 (1992)), interleukin-8 receptor $IL8R_A$ (Holmes W.E. et al., Science 2563:1278-1280(1991)), dopamine receptor D_1 (Mahan L.C. et al., Proc. Natl. Acad. Sci. USA 87:2196-2200 (1990)), metabolic glutamate receptor mGluR1 (Masu M. et al., Nature 349:760-765 (1991)), and somatostatin receptor SS_1 (Yamada Y. et al., Proc. Natl. Acad. Sci. USA 89:251-255) (for reference, Watson S. and Arkinstall S., The G protein Linked Receptor FactsBook, Academic Press (1994)). Examples of developed medicines aimed at G protein-coupled receptors are: terazosine hydrochloride (antihypertensive agent, α1 adrenoreceptor antagonist), atenolol (antiarrhythmia, β1 adrenoreceptor antagonist), dicyclomine hydrochloride (antispasmodic agent, acetylcholine receptor antagonist), ranitidine hydrochloride (drug for peptic ulcers, histamine receptor H2 antagonist), trazodone hydrochloride (antidepressant, serotonin receptor 5-HT1B antagonist), and buprenorphine hydrochloride (analgesic agent, opioid receptor κ agonist) (for reference, Stadel J.M. et al., Trends Pharm. Sci. 18:430-437 (1997); Medicine Handbook 5th edition, Yakugyo-Jiho).

[0005] The hypothalamus, a part of the brain which governs a number of programs that trigger a particular response, contributes to the homeostasis of the internal environment by means of a variety of outputs, as the center of the autonomic nervous system. For instance, it releases hormones such as thyrotropic hormone releasing hormone, gonadotropic hormone releasing hormone, and growth hormone releasing hormone, and thereby regulates the entire endocrine system through the actions of these hormones on the specific receptors expressed in target cells. These outputs in the hypothalamus are thought to be mediated by receptors expressed in the hypothalamus and compounds reacting with them. Therefore, elucidation of the relationship between the compounds regulating the hypothalamus outputs and their specific receptors expressed in the hypothalamus is extremely important in developing novel medicines for the treatment of diseases arising from endocrine disorders.

Disclosure of the Invention

[0006] The present invention provides a novel G protein-coupled receptor protein expressed in the brain (in particular, thalamus and hypothalamus, etc.). It also provides a method for screening ligands and drug-candidate compounds using said receptor protein.

[0007] The inventors first selected a region highly conserved in known G protein-coupled receptor proteins, then designed primers corresponding to the region, and performed reverse transcriptase-polymerase chain reaction (RT-PCR) using mRNA obtained from rat thalamus and hypothalamus. Next, amplified clones were randomly selected, and their partial nucleotide sequences were determined. To remove known clones from the nucleotide sequence determined-clones, colony-hybridization was performed using as a probe, cDNA clones judged to be encoding a known G protein-coupled receptor protein by homology search. Negative clones that failed to hybridize with any probe were

selected. Using probes prepared based on the nucleotide sequence of the negative clones, the inventors screened cDNA libraries from rat thalamus and hypothalamus, and succeeded in isolating a full-length cDNA encoding a rat G protein-coupled receptor. They also succeeded in isolating a full-length human cDNA corresponding to the rat cDNA. Furthermore, northern blot analysis of the tissue specificity of the gene expression showed that these genes are specifically expressed in the brain.

[0008] These G protein-coupled receptors would be extremely useful in screening for ligands and compounds that regulate the signal transduction from receptors, which are anticipated to be utilized as novel medicines.

[0009] Thus, the present invention relates to novel G protein-coupled receptor proteins that are expressed in the brain, DNAs encoding them, and a method for screening ligands and compounds that are drug-candidate compounds using the proteins.

[0010] Specifically, the invention relates to:

(1) a guanosine triphosphate binding protein-coupled receptor protein comprising the amino acid sequence of SEQ ID NO: 1, or said amino acid sequence in which one or more amino acids are replaced, deleted, or added;
(2) a guanosine triphosphate binding protein-coupled receptor protein comprising the amino acid sequence of SEQ ID NO: 20, or said amino acid sequence in which one or more amino acids are replaced, deleted, or added;
(3) a guanosine triphosphate binding protein-coupled receptor protein encoded by a DNA which hybridizes with a DNA comprising the nucleotide sequence of SEQ ID NO: 2;
(4) a guanosine triphosphate binding protein-coupled receptor protein encoded by a DNA which hybridizes with a DNA comprising the nucleotide sequence of SEQ ID NO: 21;
(5) a partial peptide of the receptor protein as described in any one of (1) to (4);
(6) a DNA encoding the receptor protein as described in any one of (1) to (4) or the partial peptide as described in (5);
(7) the DNA described in (6), wherein said DNA comprising the nucleotide sequence of SEQ ID NO: 2 or NO: 21;
(8) a vector containing the DNA as described in any one of (5) to (7);
(9) a transformant carrying the vector as described in (8);
(10) a method of producing the receptor protein as described in any one of (1) to (4) or the partial peptide as described in (5), the method comprising culturing the transformant as described in (9);
(11) a method of screening for a ligand of the receptor protein as described in any one of (1) to (4), the method comprising exposing a test compound to the receptor protein as described in any one of (1) to (4) or the partial peptide as described in (5), and selecting a compound that binds to said protein or partial peptide;
(12) a method of screening for a compound that inhibits the binding between the receptor protein as described in any one of (1) to (4) and its ligand, the method comprising,

(a) exposing a ligand to the receptor protein as described in any one of (1) to (4) or the partial peptide as described in (5) in the presence of a test compound, and detecting the binding activity between said protein or partial peptide and the ligand, and,
(b) comparing the binding activity detected in (a) with that in the absence of the test compound, and selecting a compound that reduces the binding activity between said protein or partial peptide and the ligand;

(13) a kit for screening a compound that inhibits the binding between the receptor protein as described in any one of (1) to (4) and its ligand, the kit comprising the receptor protein as described in any one of (1) to (4) or the partial peptide as described in (5); and
(14) an antibody which binds to the receptor protein as described in any one of (1) to (4).

[0011] "G protein-coupled receptor protein" herein refers to a receptor protein that transduces intracellular signals by activating G proteins. "Ligand" refers to a natural compound capable of binding to a G protein-coupled receptor and inducing signal transduction. "Agonist" refers to a compound having a bioactivity similar to that of the ligands of G protein-coupled receptors, including both natural and artificially synthesized compounds. "Antagonist" refers to a compound capable of inhibiting the bioactivity of a ligand of a G protein-coupled receptor, including both natural and artificially synthesized compounds. "Protein" and "peptide" as used herein include their salts as well.

[0012] The present invention relates to a novel G protein-coupled receptor protein. The nucleotide sequence of the cDNA encoding rat G protein-coupled receptor "BG2" isolated in the present invention is shown as SEQ ID NO; 2, and the amino acid sequence of the "BG2" protein is shown as SEQ ID NO: 1. The nucleotide sequence of the cDNA encoding human G protein-coupled receptor "BG2" isolated herein is shown as SEQ ID NO: 21, and the amino acid sequence of the human "BG2" protein is shown as SEQ ID NO: 20.

[0013] Rat "BG2" protein has 26%, 25%, and 29% homology to known G protein-coupled receptors; bovine muscarinic acetylcholine receptor M3 protein (Lee P.H. et al., Biochim. Biophys. Acta 1223:151-154 (1994)), human mus-

carinic acetylcholine receptor M5 protein (Bonner T.I. et al., Neuron 1:403-410 (1988)), and mouse α2A adrenoreceptor (Link R. et al., Mol. Pharmacol. 42:16-27 (1992)), respectively. The result of the hydrophobicity plot analysis showed that rat "BG2" protein contains hydrophobic regions (seven transmembrane regions) characteristic to G protein-coupled receptors. In addition, the coding region of the rat "BG2" cDNA has a size of approximately 1.2 kb, a size similar to that of the known G protein-coupled receptors.

[0014] Human "BG2" protein has 32%, 28%, and 27% homology to known G protein-coupled receptors; human α-2C-1 adrenoreceptor (Regan J.W. et al., Proc. Natl.Acad.Sci. USA 85:6301-6305 (1988)), mouse β-1 adrenoreceptor (Jasper J.R. et al., Biochim. Biophys. Acta 1178:307-309 (1993)), and human muscarinic acetylcholine receptor M3 protein (Peralta E.G. et al., EMBO J 6:3923-3929 (1987)), respectively.

[0015] These results suggest that the "BG2" proteins belong to the G protein-coupled receptor family, which further suggests that they participate in signal transduction through the activation of G proteins upon ligand binding.

[0016] Furthermore, the result of a northern blot analysis showed that the genes encoding the "BG2" proteins are specifically expressed in the brain. *In situ* hybridization detected a strong expression of the rat "BG2" gene in the hippocampus and spinal cord, and also in the hypothalamus, thalamus, and cerebellum.

[0017] The hippocampus plays an important role in memory and learning, the cerebellum regulates the body motions, and the hypothalamus serves as the center of the autonomic nervous system. Thus, the "BG2" proteins are assumed to be involved in the regulation of these functions. Therefore, the "BG2" proteins and genes, or an agonist or antagonist that can regulate the "BG2" protein function(s) can be used in the treatment of disabilities in memory and learning, or the control of the autonomous nervous system, such as regulation of, blood pressure, digestion, body temperature, and food-intake etc.

[0018] "BG2" protein may be prepared as natural protein, and also as recombinant protein by using recombinant DNA technology. A natural protein may be prepared, for instance, by extracting tissues such as the thalamus and hypothalamus, speculated to express "BG2" protein, and performing immunoaffinity chromatography using anti-"BG2" antibody as described later on. On the other hand, the recombinant protein can be prepared by culturing transformant cells carrying DNA encoding "BG2" protein as described later on.

[0019] One skilled in the art can prepare an altered protein having a function (transduction of intracellular signals through G protein activation) equivalent to that of the natural protein by introducing modifications such as replacement of any amino acid contained in the natural rat or human "BG2" protein (SEQ ID NO: 1, or SEQ ID NO: 20, respectively) according to known methods. Mutations of amino acids in a protein may occur naturally. The G protein-coupled receptor protein of the present invention includes such mutant proteins having an amino acid sequence altered by replacement, deletion or addition, having a function equivalent to that of the natural protein. The methods of altering amino acids, known to one skilled in the art, include, the Kunkel method (Kunkel T.A. et al., Methods Enzymol. 154:367-382 (1987)), double primer method (Zoller M.J. and Smith M., Methods Enzymol. 154:329-350 (1987)), cassette mutation (Wells et al., Gene 34:315-323 (1985)), and megaprimer method (Sarkar G. and Sommer S.S., Biotechniques 8:404-407 (1990)). The number of mutated amino acids in a functionally equivalent protein is generally not more than 10% of all the amino acids, favorably not more than 10 amino acids, and more favorably not more than 3 amino acids (for instance, one amino acid).

[0020] One skilled in the art can also use hybridization techniques (Hanahan D. and Meselson M., Methods Enzymol. 100:333-342 (1983); Benton W.D. and Davis R.W., Science 196:180-182 (1977)) to isolate a highly homologous gene from various other species based on the sequence of the rat or human "BG2" cDNA (SEQ ID NO: 2, or SEQ ID NO; 21, respectively) or a part of it, and use the isolated DNA to obtain a protein a functionally equivalent to these "BG2" proteins. Thus, it is possible for one skilled in the art to prepare a protein functionally equivalent to the rat or human "BG2" proteins, which is encoded by a DNA that hybridizes to the rat or human "BG2" cDNA. The G protein-coupled receptor protein of the present invention includes these proteins as well. Species used for isolation of a functionally equivalent protein include mouse, rabbit, sheep, bovine, dog, and pig, for instance, and particularly the brain tissues such as thalamus and hypothalamus are suitable.

[0021] DNA encoding a functionally equivalent protein to the rat or human "BG2" proteins has usually high homology to the nucleotide sequence of the rat or human "BG2" cDNA (SEQ ID NO: 2, and NO: 21). High homology generally means a sequence identity of not less than 70%, favorably not less than 80%, and more favorably not less than 90% at the nucleotide level. The sequence identity can be determined by the FASTA program.

[0022] Hybridization to isolate a DNA having high homology to the rat or human "BG2" cDNA is usually performed in "6x SSC, 40% formamide, at 25°C" followed by a wash in "1x SSC at 55°C," favorably in "6x SSC, 40% formamide, at 37°C" followed by a wash in "0.2x SSC at 55°C," and more favorably in "6x SSC, 50% formamide, at 37°C" followed by a wash in "0.1x SSC at 62°C." One skilled in the art may easily obtain a hybridization condition similar to the above conditions by appropriately selecting factors such as the dilution rate of SSC, the formamide concentration, and temperature.

[0023] The present invention also includes a partial peptide of the above-described G protein-coupled receptor protein. The partial peptide of the present invention includes, for instance, those corresponding to the N-terminal region of

the G protein-coupled receptor protein, which can be utilized to prepare an antibody. The partial peptide of the invention has a length of at least 15 amino acids, and favorably 20 amino acids.

[0024] Furthermore, the present invention relates to a DNA encoding the G protein-coupled receptor protein of the invention as described above or its partial peptide. The DNA encoding the G protein-coupled receptor protein of the invention or its partial peptide includes cDNA, genomic DNA, and synthetic DNA, but is not limited as far as it encodes the protein or the peptide. cDNA encoding the G protein-coupled receptor of the invention can be obtained by screening a cDNA library from a tissue expressing the receptor (for instance, thalamus and hypothalamus) by using as a ^{32}P-labeled probe, the cDNA as described in SEQ ID NO: 2 or NO: 21, or a part of it, complementary RNA to the DNA, or a synthetic oligonucleotide comprising a part of the cDNA. Alternatively, cDNA may be cloned by synthesizing an oligonucleotide corresponding to the nucleotide sequence of the cDNA, and amplifying cDNA from an appropriate tissue (such as thalamus and hypothalamus) by PCR. Genomic DNA can be obtained by screening a genomic library by hybridization using as a ^{32}P-labled probe, the cDNA as described in SEQ ID NO: 2 or NO: 21, or a part of it, complementary RNA to the DNA, or a synthetic oligonucleotide comprising a part of the cDNA. Alternatively, it may be cloned by synthesizing an oligonucleotide corresponding to the nucleotide sequence of the cDNA, and amplifying genome DNA by PCR. Synthetic DNA can be prepared by chemically synthesizing oligonucleotides comprising a part of the nucleotide sequence of SEQ ID NO: 2 or NO: 21, annealing them into a double strand, and ligating them using DNA ligase (Khorana H.G. et al., J. Biol. Chem. 251:565-570 (1976); Goeddel D.V. et al., Proc. Natl. Acad. Sci. USA 76:106-110 (1979)).

[0025] These DNA can be used for producing recombinant proteins. Namely, it is possible to prepare the G protein-coupled receptor protein of the invention as a recombinant protein by inserting a DNA encoding the receptor protein (DNA as described in SEQ ID NO: 2 or NO: 21, for instance) into an appropriate expression vector, culturing a transformant obtained by introducing the vector into an appropriate cell, and purifying the expressed protein. Since the G protein-coupled receptor protein of the invention is a receptor protein, it is possible to prepare it in a form expressed on the cell membrane.

[0026] Specifically, if the host is *Escherichia coli*, the plasmid vectors such as pET-3 (Rosenburg A.H. et al., Gene 56:125-135 (1987)) and pGEX-1 (Smith D.B. and Johnson K.S., Gene 67:31-40 (1988)) may be used. *E.coli* can be transformed by the Hanahan method (Hanahan D., J. Mol. Biol. 166:557-580 (1983)), electroporation (Dower W.J. et al., Nucleic Acids Res. 16:6127-6145 (1988)), and such. If the host is fission yeast (Schizosaccharomyces pombe), a plasmid vector such as pESP-1 (Lu Q. et al., Gene 200:135-144 (1997)) is used. Yeast can be transformed by spheroplast fusion (Beach D. and Nurse P., Nature 290:140 (1981)), and lithium acetate method (Okazaki K. et al., Nucleic Acids Res. 18:6485-6489 (1990)), etc.

[0027] If the host is a mammalian cell, such as Chinese Hamster ovary-derived CHO cells and human HeLa cells, vectors such as pMSG (Clontech) are used. Recombinant DNA is introduced into mammalian cells by calcium phosphate method (Graham F.L. and van derEb A.J., J. Virology 52:456-467 (1973)), DEAE-dextran method (Sussman D.J. and Milman G., Mol. Cell. Biol. 4:1641-1643 (1984)), lipofection (Felgner P.L. et al., Proc. Natl. Acad. Sci. USA 84:7413-7417 (1987)), and electroporation (Neumann E. et al., EMBO J. 1:841-845 (1982)), etc. If the host is an insect cell, a baculovirus vector such as pBacPAK8/9 (Clontech) can be used. Transformation of insect cells is done by the methods described in the literature (BioTechnology 6:47-55 (1980)).

[0028] Recombinant proteins expressed in host cells can be purified by known methods. The proteins can also be synthesized as fusion proteins tagged with histidine residues at the N-terminus, or fused to glutathione-S-transferase (GST), and purified by using their binding ability toward a metal chelating resin, or a GST affinity resin (Smith M.C. et al., J. Biol. Chem. 263:7211-7215 (1988)), respectively. For instance, when the vector pESP-1 is used, the protein of interest is synthesized as a fusion protein with GST, which can be purified using GST affinity resin. The fusion protein may be digested with thrombin, or blood coagulating factor Xa to liberate the protein of interest.

[0029] Moreover, DNA encoding the G protein-coupled receptor protein of the present invention can be used in gene therapy of diseases that arise from a mutation of the protein. When used in gene therapy, the DNA can be introduced into human cells using retrovirus vectors (Danos O. and Mulligan R.C., Proc. Natl. Acad. Sci. USA 85:6460-6464 (1988); Dranoff et al., Proc. Natl. Acad. Sci. USA 90:3539-3543 (1993)), or adenovirus vectors (Wickham T.J. et al., Cell 73:309-319 (1993)), etc. To administer the vector to patients, transplantation of bone marrow, subcutaneous injection, and intravenous injection can be used (Asano S., Protein Nucleic acid and Enzyme 40:2491-2495 (1995)).

[0030] Furthermore, the present invention relates to an antibody that is capable of binding to the G protein-coupled receptor protein of the invention. Antibodies against the G protein-coupled receptor protein can be prepared by known methods in the art (for instance, refer to Shin-Seikagaku-Jikken-Kouza I: Protein I 389-406, Tokyo-Kagaku-Doujin). For instance, polyclonal antibodies are prepared as follows. An appropriate dose of the above protein or its partial peptide is administered into immune animals such as rabbits, guinea pigs, mice, or chickens. Administration may be performed together with the adjuvant (such as FIA or FCA) that promotes antibody production, and usually performed every couple of weeks. The titer of antibodies can be increased by performing multiple immunizations. After the final immunization, antisera are obtained by withdrawing blood from immune animals. Polyclonal antibodies are purified from antisera by

ammonium sulfate precipitation, fractionation by anion exchange chromatography, or affinity chromatography with either Protein A or immobilized antigen. Monoclonal antibodies are prepared as follows. The G protein-coupled receptor proteins of the invention or its partial peptide is administered into immune animals as described above. After the final immunization, their spleens or lymph nodes are excised. Then, antigen-producing cells are recovered from the spleens or the lymph nodes, and fused with myeloma cells using polyethylene glycol etc. to produce hybridomas. Desired hybridomas are selected by screening, and their culture supernatant is used to prepare monoclonal antibodies. Monoclonal antibodies can be purified by ammonium sulfate precipitation, fractionation by anion exchange chromatography, or affinity chromatography with either Protein A or immobilized antigen. Antibodies prepared thereby can be used not only in affinity purification of the G protein-coupled receptor protein of the invention, but also for the diagnosis or antibody treatment of diseases arising from the abnormal expression of the receptors, or detection of the expression level of the receptors.

[0031] If used for antibody treatment, humanized antibodies or human antibodies are preferable. Humanized antibodies, in case of mouse-human chimeric antibodies, are prepared by isolating the gene encoding the antibody against the G protein-coupled receptor protein from the producing mouse cells, replacing the constant region of the H chain of the antibody with that of the human IgE, and introducing it into mouse myeloma J558L cells (Neuberger M.S. et al., Nature 314:268-270 (1985)). Human antibodies can be prepared by immunizing mice, whose immune system is replaced with that of human, with the G protein-coupled receptor protein.

[0032] Furthermore, the present invention relates to a method of screening ligands of the G protein-coupled receptor protein of the invention. The method includes such processes as exposing a test compound to the G protein-coupled receptor protein or its partial peptide, and selecting compounds that are capable of binding to the proteins or the peptide. Compounds to be tested include known compounds such as acetylcholine, adenosine, adrenaline, noradrenaline, angiotensin, bombesin, bradykinin, C5a,. anaphylatoxin, calcitonin, cannabinoids, chemokines, cholecystokinin, dopamine, endothelin, formylmethionylpeptide, GABA, galanin, glucagon, glutamate, glycopeptide hormone, histamine, 5-hydroxytryptophan, leucotriene, melanocortin, neuropeptide Y, neurotensin, odorant, opioid peptide, opsin, parathyroid hormone, platelet activating factor, prostanoid, somatostatin, tachykinin, thrombin, thyrotropin releasing hormone, vasopressin, and oxytocin (Watson S. and Arkinstall S., G protein Linked Receptor FactsBook, Academic Press (1994)), and also other purified proteins, expressed products of genes (including libraries), extracts of tissues or cells in which the ligand is stipulated to be expressed (the brain, thalamus, and hypothalamus etc.), and the culture medium of the cells. The G protein-coupled receptor proteins may be used in a form expressed in desired cells (including transformants genetically engineered to express the proteins) or on the cell surface, in a form of the membrane fractions of the cells, or in a form bound to an affinity column. If necessary, test compounds may be labeled appropriately. Methods for labeling include radioisotope labeling, and fluorescence labeling, but not limited thereto. The binding between the G protein-coupled receptor proteins and test compounds can be examined by detecting the label added to the compound (for instance, measuring the radioactivity or fluorescence intensity), or using as an index, intracellular signaling triggered by the compound binding to the G protein-coupled receptor protein (such as G protein activation, the change in the concentration of Ca^{2+} or cAMP, phospholipase C activation, and the change in pH). Specific methods can be employed as described in the literatures (Cell Calcium 14:663-671 (1993); Analytical Biochemistry 226:349-354 (1995); J. Biol. Chem. 268:5957-5964 (1993); Cell 92:573-585 (1998); Nature 393:272-273 (1998)), and unexamined published Japanese patent application (JP-A) No. Hei 9-268). Alternatively, the binding may be detected by measuring the activity of the reporter gene using two-hybrid system (Zervos et al., Cell 72:223-232 (1994); Fritz et al., Nature 376:530-533 (1995)).

[0033] The present invention also relates to a method of screening for a compound which can inhibit the binding between the G protein-coupled receptor proteins of the invention and their ligands. The method includes processes of (a) exposing the ligand to the G protein-coupled receptors or their partial peptides in the presence of test compound, and detecting the binding ability between the ligand and the proteins or peptides, and (b) comparing the ability detected in (a) with that in the absence of the compound, and selecting compounds which are capable of decreasing the binding ability. Compounds to be tested include proteins, peptides, non-peptide compounds, artificially synthesized compounds, extracts of tissues and cells, sera, but not limited thereto. The G protein-coupled receptor proteins may be used in a form expressed in desired cells (including transformants genetically engineered to express the proteins) or on the cell surface, in a form of the membrane fractions of the cells, or in a form bound to an affinity column. If necessary, tested compounds may be labeled appropriately. Methods for labeling include radioisotope labeling, and fluorescence labeling, but not limited thereto. The binding between the G protein-coupled receptor proteins and test compounds can be examined by detecting the label added to the compound (for instance, measuring the radioactivity or fluorescence intensity), or using intracellular signaling, as an index, that are triggered by the compound binding to the G protein-coupled receptor protein (such as G protein activation, the change in the concentration of Ca^{2+} or cAMP, phospholipase C activation, and the change in pH). Specific methods can be employed as described in the literatures (Cell Calcium 14:663-671 (1993); Analytical Biochemistry 226:349-354 (1995); J. Biol. Chem. 268:5957-5964 (1993); Cell 92:573-585 (1998); Nature 393:272-273 (1998)), and JR-A Hei 9-268). If the result of the detection showed that the binding

activity in the presence of a test compound is lower than that in the absence of the compound, the compound is judged to be capable of inhibiting the binding between the G protein-coupled receptors or their partial peptides and their ligands. These compounds include those capable of triggering the intracellular signaling through binding to the G protein-coupled receptor (agonist), and those not having such activity (antagonist). Agonists have similar bioactivities to those of the ligands of the G protein-coupled receptors. On the other hand, antagonists inhibit the bioactivities of the ligands. Therefore, these agonists and antagonists are useful as medicinal components for treatment of diseases arising from disorders in the signaling pathway mediated by the G protein-coupled receptors.

[0034] Furthermore, the present invention relates to a screening kit for compounds that inhibit the binding between the G protein-coupled receptor proteins and their ligands. The G protein-coupled receptor proteins or their partial peptides may be in a form expressed in desired cells (including transformants genetically engineered to express the protein) or on the cell surface, in a form of membrane fractions of the cell, or in a form bound to an affinity column. Components of the kit of the invention may include, other than the above described receptor protein samples, ligand samples (both labeled and unlabeled), and buffers for the reaction between the ligand and the receptor protein, and wash solutions. Labels to be added to the ligands include radioisotope and fluorescence, for instance. The kit of the invention can be used as described in JP-A Hei 9-268.

Brief Description of the Drawings

[0035]

Figure 1 shows the hydrophobicity plot of the mouse BG2 protein. The seven hydrophobic regions (transmembrane regions) that are characteristics of the G protein-coupled receptor proteins are indicated by the numbers from 1 to 7. The numbers in the bottom indicate those of the amino acid residues in the "BG2" protein.

Figure 2 shows the result of northern blot analysis of the tissue specific expression of the human and mouse BG2 genes.

Figure 3 shows the result of *in situ* hybridization analysis of the location of the mouse "BG2" gene expression in the brain.

Figure 4 shows the result of *in situ* hybridization analysis of the location of the mouse "BG2" gene expression in the spinal cord. "Sense" and "Antisense" indicate the results using sense RNA probe (not hybridizing with mRNA; negative control), and antisense RNA probe (hybridizing with mRNA), respectively.

Best Mode for Carrying out the Invention

[0036] The present invention is illustrated in detail below with reference to examples, but is not to be construed as being limited thereto.

Example 1: Isolation of a gene encoding a rat G protein-coupled receptor

[0037] The G protein-coupled receptors share a characteristic structure composed of seven transmembrane regions, and the amino acid sequences of the transmembrane regions and the adjacent regions are well conserved. The present inventors first compared the nucleotide sequences of the second and the seventh transmembrane domains, which are highly conserved, with known G protein-coupled receptors: mouse neuropeptide Y receptor Y1 (GenBank Accession Number Z18280), rat Y1 (Z11504), human Y1 (M84755), mouse neuropeptide Y receptor Y4 (U40189), rat Y4 (Z68180), human Y4 (Z66526), and mouse neuropeptide Y receptor Y6 (U58367), and synthesized novel sense and antisense primers, as described in SEQ ID NO: 3 and NO: 4, respectively.

[0038] Next, single stranded cDNA was synthesized from poly(A)$^+$RNA prepared from rat thalamus and hypothalamus using the RNA-PCR kit (TaKaRa), and PCR was performed using the two primers. Specifically, poly(A)$^+$RNA was prepared from rat thalamus and hypothalamus using Fasttrack 2.0 kit (Invitrogen). Then, 75 ng of the poly(A)$^+$RNA was used to synthesize complementary DNA according to the protocol accompanying the RNA-PCR kit (TaKaRa). PCR amplification was performed using all the cDNA. The reaction mixture comprising each 0.15 mM dNTPs, 1.5 mM $MgCl_2$, 0.025 U/μl rTaq polymerase (TaKaRa), each 0.5 μM degenerated primer Fg (SEQ ID NO: 3) and Rb (SEQ ID NO: 4), and enzyme accompanying 10x PCR buffer was prepared making a total of 130 μl, and aliquoted into six 20 μl fractions. PCR was performed with the Perlier thermal cycler PTC200 (MJ Research) under conditions as follows: a single cycle of 94°C for 2 min, followed by 35 cycles of 94°C for 30 sec, 48°C for 1 min, 72°C for 1 min 30 sec, and then a single cycle of 72°C for 8 min. After PCR, the six reaction-solutions were combined, and the amplified products were purified using the Wizard PCR purification kit (Promega), and then eluted with 30 μl TE. 2 μl of the TE eluate was used for cloning into the pCR2.1 vector of the TOPO TA cloning kit (Invitrogen). XL1-Blue cells were used as the host cell and transformed using the *E.coli* pulser (BioRad). From the resulting transformants, 5,760 colonies having white or light blue

color were randomly selected using the gene library construction system BioPick (BioRobotics), and inoculated into fifteen 384-well plates containing LB media supplemented with 100 µg/ml of ampicillin. Clones were cultured at 37°C overnight, and replica plated onto a filter on top of a LB agar plate containing 100 µg/ml ampicillin and 25% glycerol, and another filter on top of a LB agar plate containing 100 µg/ml ampicillin, for preparing a glycerol stock, and colony hybridization, respectively, using a gene library replicating system BioGrid (BioRobotics).

[0039] Since the obtained PCR clones were expected to contain multiple overlapping clones of the NPY receptor cDNA, 80 clones out of the 5,760 clones were randomly selected, and their nucleotide sequences were partially determined. To determine the nucleotide sequence, plasmid DNA purified by the plasmid automatic isolating system PI100sigma (Kurabo) was used as a template. The sequence reactions were performed using the dye-primer-cycle sequencing kit FS (Perkin Elmer), and the reaction products were separated by electrophoresis using the DNA sequencer 377 (Perkin Elmer). The homology search of the obtained sequence using the blast program of the Wisconsin package (Genetic Computer Group) showed that 29 out of the 80 clones were the cDNAs encoding the coiled-coil like protein 1 (GeneBank Accession Number U79024) while 17 clones were those of the neuropeptide Y receptor Y1 (Z11504). Then, these two cDNA fragments were used as a probe for hybridization with the filters containing a library of the degenerated PCR amplified fragments. Probes were prepared by amplifying the insert of the respective clones by PCR, purifying the products using the Wizard PCR purification kit (Promega), and labeling them with [α-^{32}P] dCTP using the Prime-It II random primer labeling kit (Stratagene). Colony hybridization was performed according to the standard method (Sambrook et al., Molecular Cloning: A laboratory manual 2nd edition (1989)). Colonies that were negative for either the coiled-coil like protein 1 or the neuropeptide Y receptor Y1 were selected and their partial nucleotide sequences were determined. For DNA sequencing, the insert fragment of each clone was amplified by PCR from the culture medium, purified using the PCR product purification kit (Amersham), and used as a template. The sequence reactions were performed using the dye-primer-cycle sequencing kit FS (Perkin Elmer), and the reaction products were separated by electrophoresis using the DNA sequencer 377 (Perkin Elmer). The obtained sequences were analyzed by the homology search using the blast program of the Wisconsin package (Genetic Computer Group), and, as a result, a clone which has significant homology to the muscarinic acetylcholine receptor M5 (GeneBank Accession Number M22926) was found. The clone has been deposited at the National Institute of Bioscience and Human-Technology, Agency of Industrial Science and Technology.

Name of the depositary institution: National Institute of Bioscience and Human-Technology,Agency of Industrial Science and Technology, MITI.
Address of the depositary institution: 1-1-3 Higashi, Tsukuba, Ibaraki 305-8566, Japan.
Date of deposit: 12/25/1997.
Accession Number: FERM BP-6575

[0040] Next, in order to isolate the full-length cDNA of the gene, cDNA libraries were prepared from rat thalamus and hypothalamus. cDNA was synthesized according to the protocol accompanying the cDNA synthesizing kit (Stratagene), and the vector pEF1x and the host XL1-blue MRF' (Stratagene) were used. The pEF1x is a refined derivative of the pcDNA3 (Invitrogen) prepared as follows.

(1) Preparation of the human EF1a promoter (GeneBank Accession Number J04617)

[0041] PCR was performed using human genomic DNA with primers (SEQ ID NO: 6/ CGAGGATCCGTGAGGCTCCGGTGCCCGTC; SEQ ID NO: 7/ CGGGTAAGCTTCACGACACCTGAAATGGAAGA). The products were digested with BamHI (TaKaRa) and HindIII (TaKaRa), and subcloned into the plasmid vector pUC19 (TaKaRa). The resulting plasmid was digested with XhoI, blunt-ended with the Klenow fragment (TaKaRa), and self-ligated using the DNA ligation kit (TaKaRa). The resulting plasmid was digested with BamHI and HindIII, and the insert was recovered.

(2) Alteration of the pcDNA3

[0042] The pcDNA3 was digested with MluI (TaKaRa), blunt-ended with the Klenow fragment (TaKaRa), and self-ligated using the DNA ligation kit. The resulting plasmid was digested with AflIII (New England Biolabs) and SmaI (TaKaRa), blunt-ended with the Klenow fragment (TaKaRa), and self-ligated using the DNA ligation kit. Then, the obtained plasmid was digested with BglII (TaKaRa) and HindIII, and the fragment depleted of the CMV promoter was recovered, and ligated with the insert fragment as described in (1) using the DNA ligation kit to construct the pEF1x.

[0043] Next, the nucleotide sequence of the cDNA fragment was used to synthesize oligonucleotide probe (SEQ ID NO: 8/ CCTTCTGCATCCCATTGTACGTACC), and multiple clones were obtained from the above cDNA libraries from rat thalamus and hypothalamus according to the protocol of the gene trapper cDNA positive selection system (GIBCO BRL). Then, colony hybridization was performed using the cDNA insert of the above isolated clone (FERM BP-6574)

as a probe, and a positive clone was obtained. This clone has been deposited at the National Institute of Bioscience and Human-Technology, Agency of Industrial Science and Technology.

Name of the depositary institution: National Institute of Bioscience and Human-Technology, Agency of Industrial Science and Technology, MITI.
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Date of deposit: 12/25/1997.
Accession Number: FERM BP-6574

[0044] The insert fragment of the clone was of 2.7 kb. Plasmid DNA was prepared by the QIAprep Midi Kit (QIAGEN), and the complete nucleotide sequence was determined using the shotgun cloning method (Sambrook et al.., Molecular Cloning: A laboratory manual 2nd edition (1989)). cDNA fragmentation was performed using the closed sonifier biomaterial treating system Biorupter (Tousou Denki), and the DNA fragments were separated by electrophoresis on a 2% agarose gel. Fragments of around 0.6 kb were purified using the gene clean spin kit (bio101), blunt-ended with T4 DNA polymerase (TaKaRa), and cloned into the HincII-BAP treated pUC118 vector, XL1-Blue was used as a host cell, and transformed using the *E.coli* pulser (BioRad). The obtained shotgun clones were sequenced using the dye-primer cycle sequencing kit FS (Perkin Elmer), or the dye-terminator cycle sequencing kit (Perkin Elmer). The resulting sequences were combined and edited to get the complete nucleotide sequence using the DNA sequencing software Sequencher (Hitachi Software). The complete nucleotide sequence is composed of 2700 bp, and turned out to be encoding a protein of 413 amino acids (SEQ ID NO: 5). Because there is a stop codon in the 5' region of the open reading frame, the cDNA is supposed to include the entire coding region (SEQ ID NO: 2). When this sequence was translated into the amino acid sequence, the hydrophobicity plot identified seven transmembrane regions from 1 to 7 (Figure 1).

[0045] In addition, the open reading frame size was approximately 1.2 kb, which is similar to that of the known G protein-coupled receptors. G protein-coupled receptor proteins have common features in their amino acid sequences, and thus form a protein family. As a result of the homology search using the amino acid sequence encoded by the isolated cDNA, the encoded protein was found to be a novel receptor protein having a homology of 26%, 25%, and 29% to known G protein-coupled receptors: bovine muscarinic acetylcholine receptor M3 protein (Lee P.H. et al., Biochim. Biophys. Acta 1223:151-154 (1994)), human muscarinic acetylcholine receptor M5 protein (Bonner T.I. et al., Neuron 1:403-410 (1988)), and mouse a2A adrenoreceptor (Link R. et al., Mol. Pharmacol. 42:16-27 (1992)), respectively.

Example 2: The isolation of the human G protein-coupled receptor gene

[0046] The obtained rat sequence was subjected to EST search to reveal a fragment of the human homologue (gene bank NID: 946030 and NID: 901756). Human fetal brain cDNA was amplified by PCR using the specific primers IF01 (SEQ ID NO: 9/ CTTCCGCCGGGCCTTCACCAA) and IR02 (SEQ ID NO: 10/ ACAGACACGGCGGGGCTCAC) (probe 1). A human λ EMBL3 SP6/T7 genomic library (Clontech) of a size of $1.2x10^6$ pfu was screened using probe 1 according to standard procedure plaque hybridization procedures. Two positive clones were thus isolated. The obtained phage-clones were digested with SacI, and three bands of a clone were subcloned. These fragments, termed I1 (SEQ ID No: 11), I3 (SEQ ID No: 12) and I5 (SEQ ID No: 13), were sequenced and a hypothetical sequence was speculated by comparing with the rat homologue. I1 and I3 were subjected to PCR amplification using specific primers YS03 (SEQ ID NO: 14/ TGAACGCTTCGGGGGCGCTG) and YS05 (SEQ ID NO: 15/ GAGATGGCGAGGTTGAGCAGG), YS12 (SEQ ID NO: 16/ GGCTCCAAGCCATCGGCGTC) and YS14(SEQ ID NO: 17/ CTCACTTCCAGCAGTGCTCC) and the PCR products were termed probe 2 and probe 3, respectively. Human hypothalamus cDNA (1.3×10^6 phage) was plated at a density of 5.6×10^4 pfu/150mm plate. The obtained sub-pools were checked by PCR using the primers YS03 and YS05. One positive sub-clone was screened in the same method as the screening of the genomic library, using probe 2. One cDNA clone containing 5'UTR to TM5 was obtained and named cDNA clone 1.

[0047] Probe 4 was amplified by PCR from cDNA clone 1 using the primers YS07 (SEQ ID NO: 18/ GCCTCCGCACCCAGAACAAC) and YS10 (SEQ ID NO: 19/ TGCGCCTCTGGATGTTCAG). Phase screening of the human hippocampus library ($3x10^6$ pfu) was done in the same method as the genomic library, using probe 3 and probe 4. A few clones were obtained and the longest one, termed cDNA clone 2, was sequenced. It has the region between TM2 and 3'UTR. cDNA clone 1 was digested by SacII, and the 3.3kb band, which contained vector and the 5'-end region, was treated by shrimp alkaline phosphatase. cDNA clone 2 was also digested by SacII, and the 1.7kb fragment was ligated into the 3.3kb fragment from cDNA clone 1. The clone into which this ligated fragment was inserted has been deposited at the National Institute of Bioscience and Human-Technology, Agency of Industrial Science and Technology.

Name of the depositary institution: National Institute of Bioscience and Human-Technology, Agency of Industrial Science and Technology, MITI.

Address of the depositary institution: 1-1-3 Higashi, Tsukuba, Ibaraki 305-8566, Japan.
Date of deposit: 12/17/1998.
Accession Number: FERM BP-6609

[0048] Human "BG2" cDNA nucleotide sequence is shown in SEQ ID NO: 21, and the amino acid sequence of the protein encoded by the said cDNA in SEQ ID NO: 20.

[0049] Human "BG2" protein had 32%, 28%, and 27% homology to known G protein-coupled receptors; human α-2C-1 adrenoreceptor (Regan J.W. et al., Proc. Natl. Acad. Sci. USA 85:6301-6305 (1988)), mouse β-1 adrenoreceptor (Jasper J.R. et al., Biochim. Biophys. Acta 1178:307-309 (1993)), and human muscarinic acetylcholine receptor M3 protein (Peralta E.G. et al., EMBO J. 6:3923-3929 (1987)), respectively.

Example 3: Northern blot analysis

[0050] Probe 4 was labeled with ^{32}Pγ-dCTP (Amersham, Prime It II) and used as cDNA probe for the detection of human "BG2". Human Multiple Tissue Northern (MTN) Blots Membrane with Express HybriTM was purchased from Clontech. After prehybridization of the membrane at 68°C for 30 min, it was hybridized with the probe at 68°C for 1 hr (final concentration of the probe was 1.5 x 10^6cpm/ml.) The blot was rinsed with 2 x SSC containing 01% SDS at 42°C for 30 min, and the final wash was done at 50°C for 30 min in 0.1 x SSC containing 0.1% SDS. The blot was then exposed at -80°C for 2.5 days to Kodak autoradiographic film.

[0051] For the detection of the mouse "BG2," probe was prepared by PCR amplifying using the rat "BG2" cDNA as a template with sense primer MF2 (SEQ ID NO: 22/ TGCATCCCATTGTACGTNCC), and antisense primer MR1 (SEQ ID NO: 24/ TGCTCTGGGACACCATCTTC), purifying the amplified products by electrophoresis on an agarose gel, and labeling them as above described for human gene.

[0052] Blotting membrane used was the Rat MTN (Multiple Tissue Northern) blot (Clontech). Hybridization was performed at 42°C overnight in hybridization buffer (50% formamide, 4x SSPE, 1% SDS, 0.5% BLOTTO, and 100 µg/ml salmon sperm DNA). The membrane was washed at 65°C in 0.1x SSC containing 0.1% SDS, and then exposed to the Kodak autoradiography film at -80°C overnight.

[0053] The result showed that the human and rat "BG2" genes are strongly expressed particularly in the brain (Fig. 2).

Example 4: *In situ* Hybridization

[0054] Adult male Sprague-Dawley rats (Charles River Japan) aged 13-18 weeks were anesthetized with inhalation of ether, connected to a rotary pump and infused with chilled 4% paraformaldehyde in phosphate buffer (pH7.2) via a cannula inserted into the left ventricle. After perfusion, brain, pituitary and spinal cord were removed and dissected to sagittal or coronal sections. The tissue specimens were postfixed with the same fixative overnight at 4°C. The following process was carefully done to avoid RNA contamination. Tissue specimens were embedded in paraffin wax in a routine manner, then paraffin sections were cut into a thickness of 6 µm by rotary microtome (Model HM 355; MICROM Laborgerate GmbH). The sections were stored in moisture free condition at -20°C until proceeded to *in situ* hybridization.

[0055] For preparation of rat BG2 sense and antisense RNA probes, the cDNA fragment, amplified by PCR from MP-21 plasmid DNA using a sense primer MF2 (SEQ ID NO:22/ TGCATCCCATTGTACGTNCC) and antisense primer MR3 (SEQ ID NO:23/ ATCATTAGGAGCGTGTANGG), was cloned into pZErO-2 vector (Invitrogen). The RNA probes were labeled with digoxigenin using DIG RNA Labeling Kit (Boehringer Mannheim). Paraffin sections were de-paraffinized with xylene and transferred to distilled water after rinsing with graded ethyl alcohol. *In situ* Hybridization Reagents (ISHR, Code No. 316-01951; Nippon Gene) were used as reagents without digoxigenin-labeled RNA. The sections were incubated with two changes of phosphate buffer saline(PBS;ISHR 1) for 1 min and 10 min. The sections were treated with proteinase K (ISHR 6) for 10 min at 37°C . Acetylation was done with acetylation buffer (ISHR 3) containing acetic anhydride (ISHR 4) for 15 min, followed by quenching with PBS/glycine buffer (ISHR 2) for 20 min at room temperature, rinsed twice with 4 x SSC (ISHR 5) for 10 min and then rinsed with PBS buffer for 10 min. After pre-hybridization with 50% formamide/2 x SSC for 30 min at room temperature, hybridization was performed for 16 hr at 42 °C using digoxigenin-labeled RNA probe (1 µg/ml).

[0056] Post hybridization washing was performed twice 50% formamide/2 x SSC for 10 min at 42°C . Then the sections were treated with RNase A (ISHR10)/NET buffer (ISHR 9) for 30 min at 37°C after rinsing with NET buffer (ISHR 9) for 5 min at 37°C. After washing twice with 0.1 x SSC buffer (ISHR 11) for 20 min, the sections were transferred and labeled digoxigenin was detected using the Digoxigenin Detection Kit (Boehringer Manheim). Then the sections were rinsed with 100 mM Tris-Hcl, 150 mM NaCl containing buffer (Buffer 1) for 1 min at room temperature then incubated with blocking reagent (Buffer 2) for 30 min at room temperature. The sections were incubated with anti-digoxigenin alka-

line phosphatase-labeled antibody for 60 min at room temperature. After washing with Buffer 1 for 15 min and Buffer 3 for 2 min at room temperature, the solutions were incubated with NBT/X-phosphate solution diluted with Buffer 3 for 12-14 hr at room temperature. The sections were mounted with glycerol or Permount after washing with Buffer 4.

[0057] As a result, as shown in Figures 3 and 4, BG2 cDNA probe was strongly hybridized to the hippocampus and the spinal cord. Hybridization of a medium extent was also detected in hypothalamus and cerebellum.

Industrial Applicability

[0058] The present invention has provided novel G protein-coupled receptor proteins specifically expressed in the brain, and their genes. Use of the receptors makes it possible to screen their ligands and compounds that are candidates for medicines. These ligands and candidate compounds would be useful in the diagnosis and treatment of diseases arising from disorders of signal transduction pathway mediated by the G protein-coupled receptor of the invention.

SEQUENCE LISTING

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Ala Val Leu Ala Ala Leu Met Ala Leu Leu Ile Val Ala Thr Val Leu
35                  40                  45                  50

ggc aac gcg ctg gtc atg ctc gcc ttc gtg gcg gat tcg agc ctc cgc        548
Gly Asn Ala Leu Val Met Leu Ala Phe Val Ala Asp Ser Ser Leu Arg
                55                  60                  65

acc cag aac aac ttc ttt ctg ctc aac ctc gcc atc tcc gac ttc ctc        596
Thr Gln Asn Asn Phe Phe Leu Leu Asn Leu Ala Ile Ser Asp Phe Leu
            70                  75                  80
```

```
gtg ggt gcc ttc tgc atc cca ttg tac gta ccc tat gtg ctg acc ggc      644
Val Gly Ala Phe Cys Ile Pro Leu Tyr Val Pro Tyr Val Leu Thr Gly
        85                  90                  95

cgt tgg acc ttc ggc cgg ggc ctc tgc aag ctg tgg ctg gtg gta gac      692
Arg Trp Thr Phe Gly Arg Gly Leu Cys Lys Leu Trp Leu Val Val Asp
    100                 105                 110

tac cta ctg tgt gcc tcc tcg gtc ttc aac atc gta ctc atc agc tat      740
Tyr Leu Leu Cys Ala Ser Ser Val Phe Asn Ile Val Leu Ile Ser Tyr
115                 120                 125                 130

gac cga ttc ctg tca gtc act cga gct gtc tcc tac agg gcc cag cag      788
Asp Arg Phe Leu Ser Val Thr Arg Ala Val Ser Tyr Arg Ala Gln Gln
                135                 140                 145

ggg gac acg aga cgg gcc gtt cgg aag atg gca ctg gtg tgg gtg ctg      836
Gly Asp Thr Arg Arg Ala Val Arg Lys Met Ala Leu Val Trp Val Leu
            150                 155                 160

gcc ttc ctg ctg tat ggg cct gcc atc ctg agt tgg gag tac ctg tct      884
Ala Phe Leu Leu Tyr Gly Pro Ala Ile Leu Ser Trp Glu Tyr Leu Ser
        165                 170                 175

ggt ggc agt tcc atc ccc gag ggc cac tgc tat gct gag ttc ttc tac      932
Gly Gly Ser Ser Ile Pro Glu Gly His Cys Tyr Ala Glu Phe Phe Tyr
    180                 185                 190

aac tgg tac ttt ctc atc acg gcc tcc acc ctc gag ttc ttc acg ccc      980
Asn Trp Tyr Phe Leu Ile Thr Ala Ser Thr Leu Glu Phe Phe Thr Pro
195                 200                 205                 210

ttc ctc agc gtt acc ttc ttc aac ctc agc atc tac ctg aac atc cag     1028
Phe Leu Ser Val Thr Phe Phe Asn Leu Ser Ile Tyr Leu Asn Ile Gln
                215                 220                 225

agg cgc acc cgc ctt cgg ctt gat ggg ggc cgt gag gct ggc cca gaa     1076
Arg Arg Thr Arg Leu Arg Leu Asp Gly Gly Arg Glu Ala Gly Pro Glu
            230                 235                 240

ccc cca cca gat gcc cag ccc tcg cca cct cca gct ccc ccc agc tgc     1124
```

```
Pro Pro Pro Asp Ala Gln Pro Ser Pro Pro Pro Ala Pro Pro Ser Cys
        245                 250                 255

tgg ggc tgc tgg cca aaa ggg cat ggc gag gcc atg ccg ttg cac agc      1172
Trp Gly Cys Trp Pro Lys Gly His Gly Glu Ala Met Pro Leu His Ser
    260                 265                 270

tct ggc agc tcc tca agg ggc act gag agg cca cgc tca ctc aaa agg      1220
Ser Gly Ser Ser Ser Arg Gly Thr Glu Arg Pro Arg Ser Leu Lys Arg
275                 280                 285                 290

ggc tcc aag cca tca gca tct tca gca tcc ctg gag aag cgc atg aag      1268
Gly Ser Lys Pro Ser Ala Ser Ser Ala Ser Leu Glu Lys Arg Met Lys
                295                 300                 305

atg gtg tcc cag agc atc acc cag cgc ttc cgg ctg tcg cgg gac aag      1316
Met Val Ser Gln Ser Ile Thr Gln Arg Phe Arg Leu Ser Arg Asp Lys
            310                 315                 320

aag gtg gcc aag tcg ctg gcc atc atc gtg agc atc ttt ggg ctc tgc      1364
Lys Val Ala Lys Ser Leu Ala Ile Ile Val Ser Ile Phe Gly Leu Cys
        325                 330                 335

tgg gcg ccg tac acg ctc cta atg atc atc cga gct gct tgc cat ggc      1412
Trp Ala Pro Tyr Thr Leu Leu Met Ile Ile Arg Ala Ala Cys His Gly
    340                 345                 350

cgc tgc atc ccc gat tac tgg tac gag acg tcc ttc tgg ctt ctg tgg      1460
Arg Cys Ile Pro Asp Tyr Trp TyrGlu Thr Ser Phe Trp Leu Leu Trp
355                 360                 365                 370

gcc aac tcg gcc gtc aac ccc gtc ctc tac cca ctg tgc cac tac agc      1508
Ala Asn Ser Ala Val Asn Pro Val Leu Tyr Pro Leu Cys His Tyr Ser
                375                 380                 385

ttc cgc aga gcc ttc acc aag ctc ctc tgc ccc cag aag ctc aag gtc      1556
Phe Arg Arg Ala Phe Thr Lys Leu Leu Cys Pro Gln Lys Leu Lys Val
            390                 395                 400

cag ccc cac ggc tcc ctg gag cag tgc tgg aag tgagcagctg ccccaccctt    1609
Gln Pro His Gly Ser Leu Glu Gln Cys Trp Lys
```

405 410

ctgaggccag gcccttgtac ttgtttgagt gggcagccgg agcgtgggcg gggccctggt 1669

ccatgctccg ctccaaatgc catggcggcc tcttagatca tcaaccccgc agtggggtag 1729

catggcaggt gggccaagag ccctagttgg tggagctaga gtgtgctggt tagctctgcc 1789

gccacattct ccttcaccac acagaagaga caatccagga gtcccaggca tgccttccac 1849

ctacacacac acacacacac acacacacac acacaccaca gtgcagtgcc agtgatgtcc 1909

ccttttgcat atttagtggt tggtgtcctc cctaatgcaa acctcggtgt gtgctcccgg 1969

ctccggccct ggcaatgcgt gcgtgcgccc tgcatgtgct cacacccgcc acacacccgc 2029

ccgccacaca cttgcaacac ctcctctctc ccagaagagc tggggacgat gccctttgct 2089

gccactgtct cttgcttaat cccagagcct ggctccttat cccccactct cccttcaact 2149

ctgccccaca aagtgtcgag cgcctcggga aacttgaagc ttctctgctc cttccactct 2209

ggatgtttcc aggaagatgg aggagaagaa aacacgtctg tgaacttgat gttccttgga 2269

tgtttaatca agagagacaa aattgccgag gagctcgggg ctggattggc aggtgtgggc 2329

tcccacgccc tcctccctca gtgctgcagc ttccggctga gccgcgccag ctgcttctgc 2389

ctgccccgcc cccaggcttg ggacgatggc cctgccctgc ttgccccgtc tgtacaatca 2449

gaatttgggg gtgggtggtt atggggtaga gcggctcttc actgtgccct aaaggtcctg 2509

aggctcacag gacagtcagc aggagagcag gcaggcccgc gacacctggg aggaatgctt 2569

tgcctcgtcc tgtgtactca cctcaggctt ctgcatgctc tgctgccctt gtgccctggt 2629

gtgctgcctc tgccaatgtg aaaacacaat aaagtgtatt ttttttacgga aaaaaaaana 2689

aaaaaaaaaa a 2700

<210> 6
<211> 29
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 6
cgaggatccg tgaggctccg gtgcccgtc 29

<210> 7
<211> 32
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 7
cgggtaagct tcacgacacc tgaaatggaa ga 32

<210> 8
<211> 24
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 8
ccttctgcat cccattgtac gtacc 24

<210> 9
<211> 21
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 9
cttccgccgg gccttcacca a 21

<210> 10
<211> 24
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 10
acagacacgg cggggctcac 20

<210> 11
<211> 1350
<212> DNA
<213> Homo sapiens

<220>
<221> exon
<222> (280)..(557)

<400> 11
gcactcggct gcgcgttgcn tccggctgca cggtcgcacc ggcagcggct caggctccgg 60

ctcctctccc gctgcagcag ccgcgctgcc ggccccactg ggctcggatc cggccccggc 120

cccctcggca ccgcctgctc tggccccggc cccggccccg cggaccatgc gctgggcgcc 180

cccaggggaa cccgacccgg ccaagggccc gcaaagacga ggctcccggg ccggggcccc 240

tcccggccgc ccagctctcg gccggcgccc tgccccgcgt cccggagccg cgtgagcctg 300

cggggccatg gagcgcgcgc cgcccgacgg gccgctgaac gcttcggggg cgctggcggg 360

cgaggcggcg gcggcgggcg gggcgcgcgg cttctcggca gcctggaccg cggtgctggc 420

cgcgctcatg gcgctgctca tcgtggccac ggtgctgggc aacgcgctgg tcatgctcgc 480

cttcgtggcc gactcgagcc tccgcaccca gaacaacttc ttcctgctca acctcgccat 540

ctccgacttc ctcgtcggta aatccccagc ccctggccgc tggggaccca ggggcgccca 600

gcgtggccgg gccagcgggg actggaacac ggacctgggt ggctcccgca ggcacacgcc 660

ccaccagggg acccggcctg ggaaggggge gtccggagcc catggggtgg ggggcacagg 720

cgaagttcct tgccactcag gcctcgggac aggggctggg gagagatgtc cccgggaagg 780

gacacgggca ctgggcgagg cgcaaggcgc aaaggcagcg ggtgcagctc tggctcctgc 840

gctgtagcca aacaaaggct gctgcggact taggacgcgc ggagggcgca gtggggcggt 900

ttagagaagg tctgggggag gggacatgga agggggattt ttagagctgt gttgggggaa 960

gggacggtgg ggaaggtggg ggttgggggа gacgctcgga ggagcgtgct ctcacgtgtc 1020

caggctctgc tgccggctgg ggggcggggc acgcggaggg ggctggagcg ccagacacct 1080

gttggggctg tgaggtgcgt ctcccagacg ctccaagccc gcttggcagt agtagtagcg 1140

gctggcggct ggcggctgca accaagtgcc ctttcagcca ggagaaaggc tttctccttg 1200

tctaagctga gaccgagggt tgtccagcgc cagggtaggg gctggagtcc agcgggggag 1260

gggagaagga aattgtcttc tttcctcctt tgagggctgg gagggctgga cagaagtcca 1320

gggaatcccg actccaggct ctcgggggtc 1350

<210> 12
<211> 448
<212> DNA
<213> Homo sapiens

<220>
<221> exon
<222> (259)..(425)

<400> 12
gagctcccca tgcctggatc atccctcctg cccccaggcc caggggacac agatagtgct 60

gggagctatg tgggggtgaa ggctggcggc agggcagagt ttgtggctga caccaggtgg 120

aggggtggta agatgaggat ggctagttcc agaaaagcag ccaccatgtg accccaggtc 180

ccgcccggtgt ctgcgcttag gtccgtctgt cccctggccc ctggctgcat ggtcccactg 240

tggccctact ccccacaggc gccttctgca tcccactgta tgtaccctac gtgctgacag 300

gccgctggac cttcggccgg ggcctctgca agctgtggct ggtagtggac tacctgctgt 360

gcacctcctc tgccttcaac atcgtgctca tcagctacga ccgcttcctg tcggtcaccc 420

gagcggtgag tcctgggctg cggagctc 448

<210> 13
<211> 1893
<212> DNA
<213> Homo sapiens

<220>
<221> exon
<222> (293)..(1209)

<400> 13
gagctcacag ctggtagggg gtggtaaaca ggcagcctag cagagagtga gggttcaggt 60

tggtcccagg gagcttctga ggctctcact gagtgtggca gggcaccagt ccgggacccc 120

agtggggagg gttagaggaa gggaggggaa agagggaggg agggaggaca ggaggggaaa 180

ggaggagcat tgctgctgag ggaagggccc acataggggc ccacaggcta cgggggcgca 240

cccagcccaa tattccttcc gccccgcccc tgaccagcct gcccttctgc aggtctcata 300

ccgggcccag cagggtgaca cgcggcgggc agtgcggaag atgctgctgg tgtgggtgct 360

ggccttcctg ctgtacggac cagccatcct gagctgggag tacctgtccg ggggcagctc 420

catccccgag ggccactgct atgccgagtt cttctacaac tggtacttcc tcatcacggc 480

ttccaccctg gagttcttta cgcccttcct cagcgtcacc ttctttaacc tcagcatcta 540

cctgaacatc cagaggcgca cccgcctccg gctggatggg gctcgagagg cagccggccc 600

cgagcccccc cccgaggccc agccctcacc acccccaccg cctggctgct ggggctgctg 660

gcagaagggg cacggggagg ccatgccgct gcacaggtat ggggtgggtg aggcggccgt 720

aggcgctgag gccggggagg cgaccctcgg gggtggcggt gggggcggct ccgtggcttc 780

acccacctcc agctccggca gctcctcgag gggcactgag aggccgcgct cactcaagag 840

gggctccaag ccatcggcgt cctcggcctc actggagaag cgcatgaaga tggtgtccca 900

gagcttcacc cagcgctttc ggctgtctcg ggacaggaaa gtggccaagt cgctggccgt 960

catcgtgagc atctttgggc tctgctgggc cccatacacg ctgctgatga tcatccgggc 1020

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tcctgggcat ctggccctgc tgcccccctac ccggctcgtt cccccagggg tgagccccgc 1320

cgtgtctgtg gccctctctt aatgccacgg cagccaccct gccatggagg cgccttcctg 1380

ggttggctag agggcccctc actggctgga ctggaggctg ggtggccggc cctgcccccc 1440

acattctggc tccaccggga gggacagtct ggaggtccca gacatgctgc ccaccccctg 1500

ctggtgccca cccttcgcag ttactggttg gtgttcttcc caaagcaagc acctgggtgt 1560

gctccaggct tcctgcccta gcagtttgcc tctgcacgtg cacacacctg cacacccctg 1620

cacacacctg cacaccgtcc ctctccccgg acaagcccag gacactgcct ttgctgcctt 1680

ctgtctcttg cataagcctc aggcctggcc ctttcacccc tcttcccacc aactctctct 1740

gcccccaaaa gtgtcaaggg gccctaggaa cctcgaagct gttctctgct tttccattct 1800

gggtgttttc agaaagatga agaagaaaac atgtctgtga acttgatgtt cctgggatgt 1860

ttaatcaaga gagacaaaat tgctgaggag ctc 1893

<210> 14
<211> 20
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 14
tgaacgcttc gggggcgctg 20

<210> 15
<211> 21
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 15
gagatggcga ggttgagcag g 21

<210> 16
<211> 20
<212> DNA

<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 16
ggctccaagc catcggcgtc 20

<210> 17
<211> 20
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 17
ctcacttcca gcagtgctcc 20

<210> 18
<211> 20
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 18
gcctccgcac ccagaacaac 20

<210> 19
<211> 19
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

<400> 19
tgcgcctctg gatgttcag 19

<210> 20
<211> 453
<212> PRT
<213> Homo sapiens

<400> 20
Met Glu Arg Ala Pro Pro Asp Gly Pro Leu Asn Ala Ser Gly Ala Leu
1 5 10 15

Ala Gly Glu Ala Ala Ala Ala Gly Gly Ala Arg Gly Phe Ser Ala Ala
20 25 30

Trp Thr Ala Val Leu Ala Ala Leu Met Ala Leu Leu Ile Val Ala Thr
35 40 45

Val Leu Gly Asn Ala Leu Val Met Leu Ala Phe Val Ala Asp Ser Ser
50 55 60

Leu Arg Thr Gln Asn Asn Phe Phe Leu Leu Asn Leu Ala Ile Ser Asp
65 70 75 80

Phe Leu Val Gly Ala Phe Cys Ile Pro Leu Tyr Val Pro Tyr Val Leu
85 90 95

Thr Gly Arg Trp Thr Phe Gly Arg Gly Leu Cys Lys Leu Trp Leu Val
100 105 110

Val Asp Tyr Leu Leu Cys Thr Ser Ser Ala Phe Asn Ile Val Leu Ile
115 120 125

Ser Tyr Asp Arg Phe Leu Ser Val Thr Arg Ala Val Ser Tyr Arg Ala
130 135 140

Gln Gln Gly Asp Thr Arg Arg Ala Val Arg Lys Met Leu Leu Val Trp
145 150 155 160

Val Leu Ala Phe Leu Leu Tyr Gly Pro Ala Ile Leu Ser Trp Glu Tyr

```
                165                 170                 175

Leu Ser Gly Gly Ser Ser Ile Pro Glu Gly His Cys Tyr Ala Glu Phe
            180                 185                 190

Phe Tyr Asn Trp Tyr Phe Leu Ile Thr Ala Ser Thr Leu Glu Phe Phe
        195                 200                 205

Thr Pro Phe Leu Ser Val Thr Phe Phe Asn Leu Ser Ile Tyr Leu Asn
    210                 215                 220

Ile Gln Arg Arg Thr Arg Leu Arg Leu Asp Gly Ala Arg Glu Ala Ala
225                 230                 235                 240

Gly Pro Glu Pro Pro Pro Glu Ala Gln Pro Ser Pro Pro Pro Pro Pro
                245                 250                 255

Gly Cys Trp Gly Cys Trp Gln Lys Gly His Gly Glu Ala Met Pro Leu
            260                 265                 270

His Arg Tyr Gly Val Gly Glu Ala Ala Val Gly Ala Glu Ala Gly Glu
        275                 280                 285

Ala Thr Leu Gly Gly Gly Gly Gly Gly Gly Ser Val Ala Ser Pro Thr
    290                 295                 300

Ser Ser Ser Gly Ser Ser Ser Arg Gly Thr Glu Arg Pro Arg Ser Leu
305                 310                 315                 320

Lys Arg Gly Ser Lys Pro Ser Ala Ser Ser Ala Ser Leu Glu Lys Arg
                325                 330                 335

Met Lys Met Val Ser Gln Ser Phe Thr Gln Arg Phe Arg Leu Ser Arg
            340                 345                 350

Asp Arg Lys Val Ala Lys Ser Leu Ala Val Ile Val Ser Ile Phe Gly
        355                 360                 365

Leu Cys Trp Ala Pro Tyr Thr Leu Leu Met Ile Ile Arg Ala Ala Cys
    370                 375                 380
```

His Gly His Cys Val Pro Asp Tyr Trp Tyr Glu Thr Ser Phe Trp Leu
385 390 395 400

Leu Trp Ala Asn Ser Ala Val Asn Pro Val Leu Tyr Pro Leu Cys His
405 410 415

His Ser Phe Arg Arg Ala Phe Thr Lys Leu Leu Cys Pro Gln Lys Leu
420 425 430

Lys Ile Gln Pro His Ser Ser Leu Glu His Cys Trp Lys Lys Met Lys
435 440 445

Lys Lys Thr Cys Leu
450

<210> 21
<211> 2050
<212> DNA
<213> Homo sapiens

<220>
<221> CDS
<222> (271)..(1629)

<400> 21
agagatgtag ggcgcccctt ttagctgcgc acagaacgaa agaactcgtt ttttctttaa 60

gtgagtgtgc ttgggtgacg cttagggcgc cctccgcagt gcgcgcagga aagcgcactg 120

aggctgcgga ggcagagctg catgctgggt gcgggaagag gtgggctccg tcgcggagtc 180

gctgagtccg tgccctttta gttagttctg cagtctagta tggtccccat ttgcccttcc 240

actcccggag ccgcgtgagc ctgcgggggcc atg gag cgc gcg ccg ccc gac ggg 294
Met Glu Arg Ala Pro Pro Asp Gly
1 5

ccg ctg aac gct tcg ggg gcg ctg gcg ggc gag gcg gcg gcg gcg ggc 342
Pro Leu Asn Ala Ser Gly Ala Leu Ala Gly Glu Ala Ala Ala Ala Gly
10 15 20

```
ggg gcg cgc ggc ttc tcg gca gcc tgg acc gcg gtg ctg gcc gcg ctc   390
Gly Ala Arg Gly Phe Ser Ala Ala Trp Thr Ala Val Leu Ala Ala Leu
 25                  30                  35                  40

atg gcg ctg ctc atc gtg gcc acg gtg ctg ggc aac gcg ctg gtc atg   438
Met Ala Leu Leu Ile Val Ala Thr Val Leu Gly Asn Ala Leu Val Met
                 45                  50                  55

ctc gcc ttc gtg gcc gac tcg agc ctc cgc acc cag aac aac ttc ttc   486
Leu Ala Phe Val Ala Asp Ser Ser Leu Arg Thr Gln Asn Asn Phe Phe
             60                  65                  70

ctg ctc aac ctc gcc atc tcc gac ttc ctc gtc ggc gcc ttc tgc atc   534
Leu Leu Asn Leu Ala Ile Ser Asp Phe Leu Val Gly Ala Phe Cys Ile
         75                  80                  85

cca ctg tat gta ccc tac gtg ctg aca ggc cgc tgg acc ttc ggc cgg   582
Pro Leu Tyr Val Pro Tyr Val Leu Thr Gly Arg Trp Thr Phe Gly Arg
     90                  95                 100

ggc ctc tgc aag ctg tgg ctg gta gtg gac tac ctg ctg tgc acc tcc   630
Gly Leu Cys Lys Leu Trp Leu Val Val Asp Tyr Leu Leu Cys Thr Ser
105                 110                 115                 120

tct gcc ttc aac atc gtg ctc atc agc tac gac cgc ttc ctg tcg gtc   678
Ser Ala Phe Asn Ile Val Leu Ile Ser Tyr Asp Arg Phe Leu Ser Val
                125                 130                 135

acc cga gcg gtc tca tac cgg gcc cag cag ggt gac acg cgg cgg gca   726
Thr Arg Ala Val Ser Tyr Arg Ala Gln Gln Gly Asp Thr Arg Arg Ala
            140                 145                 150

gtg cgg aag atg ctg ctg gtg tgg gtg ctg gcc ttc ctg ctg tac gga   774
Val Arg Lys Met Leu Leu Val Trp Val Leu Ala Phe Leu Leu Tyr Gly
        155                 160                 165

cca gcc atc ctg agc tgg gag tac ctg tcc ggg ggc agc tcc atc ccc   822
Pro Ala Ile Leu Ser Trp Glu Tyr Leu Ser Gly Gly Ser Ser Ile Pro
    170                 175                 180

gag ggc cac tgc tat gcc gag ttc ttc tac aac tgg tac ttc ctc atc   870
```

```
Glu Gly His Cys Tyr Ala Glu Phe Phe Tyr Asn Trp Tyr Phe Leu Ile
185                 190                 195                 200

acg gct tcc acc ctg gag ttc ttt acg ccc ttc ctc agc gtc acc ttc   918
Thr Ala Ser Thr Leu Glu Phe Phe Thr Pro Phe Leu Ser Val Thr Phe
                205                 210                 215

ttt aac ctc agc atc tac ctg aac atc cag agg cgc acc cgc ctc cgg   966
Phe Asn Leu Ser Ile Tyr Leu Asn Ile Gln Arg Arg Thr Arg Leu Arg
            220                 225                 230

ctg gat ggg gct cga gag gca gcc ggc ccc gag ccc cct ccc gag gcc   1014
Leu Asp Gly Ala Arg Glu Ala Ala Gly Pro Glu Pro Pro Pro Glu Ala
        235                 240                 245

cag ccc tca cca ccc cca ccg cct ggc tgc tgg ggc tgc tgg cag aag   1062
Gln Pro Ser Pro Pro Pro Pro Pro Gly Cys Trp Gly Cys Trp Gln Lys
    250                 255                 260

ggg cac ggg gag gcc atg ccg ctg cac agg tat ggg gtg ggt gag gcg   1110
Gly His Gly Glu Ala Met Pro Leu His Arg Tyr Gly Val Gly Glu Ala
265                 270                 275                 280

gcc gta ggc gct gag gcc ggg gag gcg acc ctc ggg ggt ggc ggt ggg   1158
Ala Val Gly Ala Glu Ala Gly Glu Ala Thr Leu Gly Gly Gly Gly Gly
                285                 290                 295

ggc ggc tcc gtg gct tca ccc acc tcc agc tcc ggc agc tcc tcg agg   1206
Gly Gly Ser Val Ala Ser Pro Thr Ser Ser Ser Gly Ser Ser Ser Arg
            300                 305                 310

ggc act gag agg ccg cgc tca ctc aag agg ggc tcc aag ccg tcg gcg   1254
Gly Thr Glu Arg Pro Arg Ser Leu Lys Arg Gly Ser Lys Pro Ser Ala
        315                 320                 325

tcc tcg gcc tcg ctg gag aag cgc atg aag atg gtg tcc cag agc ttc   1302
Ser Ser Ala Ser Leu Glu Lys Arg Met Lys Met Val Ser Gln Ser Phe
    330                 335                 340

acc cag cgc ttt cgg ctg tct cgg gac agg aaa gtg gcc aag tcg ctg   1350
Thr Gln Arg Phe Arg Leu Ser Arg Asp Arg Lys Val Ala Lys Ser Leu
```

345 350 355 360

gcc gtc atc gtg agc atc ttt ggg ctc tgc tgg gcc cca tac acg ctg 1398
Ala Val Ile Val Ser Ile Phe Gly Leu Cys Trp Ala Pro Tyr Thr Leu
365 370 375

ctg atg atc atc cgg gcc gcc tgc cat ggc cac tgc gtc cct gac tac 1446
Leu Met Ile Ile Arg Ala Ala Cys His Gly His Cys Val Pro Asp Tyr
380 385 390

tgg tac gaa acc tcc ttc tgg ctc ctg tgg gcc aac tcg gct gtc aac 1494
Trp Tyr Glu Thr Ser Phe Trp Leu Leu Trp Ala Asn Ser Ala Val Asn
395 400 405

cct gtc ctc tac ccc ctg tgc cac cac agc ttc cgc cgg gcc ttc acc 1542
Pro Val Leu Tyr Pro Leu Cys His His Ser Phe Arg Arg Ala Phe Thr
410 415 420

aag ctg ctc tgc ccc cag aag ctc aaa atc cag ccc cac agc tcc ctg 1590
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425 430 435 440

gag cac tgc tgg aaa aag atg aag aag aaa aca tgt ctg tgaacttgat 1639
Glu His Cys Trp Lys Lys Met Lys Lys Lys Thr Cys Leu
445 450

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ccatgtgctg tgcacccgtg ccacgcgctc tgcatgctcc tctgcctgtg cccgctgcgc 1999

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<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

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<210> 23
<211> 20
<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

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<212> DNA
<213> Artificial Sequence

<220>
<223> Description of Artificial Sequence: Artificially synthesized primer sequence

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Claims

1. A guanosine triphosphate binding protein-coupled receptor protein comprising the amino acid sequence of SEQ ID NO: 1, or said amino acid sequence in which one or more amino acids are replaced, deleted, or added.

2. A guanosine triphosphate binding protein-coupled receptor protein comprising the amino acid sequence of SEQ ID NO: 20, or said amino acid sequence in which one or more amino acids are replaced, deleted, or added.

3. A guanosine triphosphate binding protein-coupled receptor protein encoded by a DNA which hybridizes with a DNA comprising the nucleotide sequence of SEQ ID NO: 2.

4. A guanosine triphosphate binding protein-coupled receptor protein encoded by a DNA which hybridizes with a DNA comprising the nucleotide sequence of SEQ ID NO: 21.

5. A partial peptide of the receptor protein as described in any one of claims 1 to 4.

6. A DNA encoding the receptor protein as described in any one of claims 1 to 4 or the partial peptide as described in claim 5.

7. The DNA described in claim 6, wherein said DNA comprising the nucleotide sequence of SEQ ID NO: 2 or NO: 21.

8. A vector containing the DNA as described in any one of claims 5 to 7.

9. A transformant carrying the vector as described in claim 8.

10. A method of producing the receptor protein as described in any one of claims 1 to 4 or the partial peptide as described in claim 5, the method comprising culturing the transformant as described in claim 9.

11. A method of screening for a ligand of the receptor protein as described in any one of claims 1 to 4, the method comprising exposing a test compound to the receptor protein as described in any one of claims 1 to 4 or the partial peptide as described in claim 5, and selecting a compound that binds to said protein or partial peptide.

12. A method of screening for a compound that inhibits the binding between the receptor protein as described in any one of claims 1 to 4 and its ligand, the method comprising,

    (a) exposing a ligand to the receptor protein as described in any one of claims 1 to 4 or the partial peptide as described in claim 5 in the presence of a test compound, and detecting the binding activity between said protein or partial peptide and the ligand, and,
    (b) comparing the binding activity detected in (a) with that in the absence of the test compound, and selecting a compound that reduces the binding activity between said protein or partial peptide and the ligand.

13. A kit for screening a compound that inhibits the binding between the receptor protein as described in any one of claims 1 to 4 and its ligand, the kit comprising the receptor protein as described in any of claims 1 to 4 or the partial peptide as described in claim 5.

14. An antibody which binds to the receptor protein as described in any one of claims 1 to 4.

Figure 1

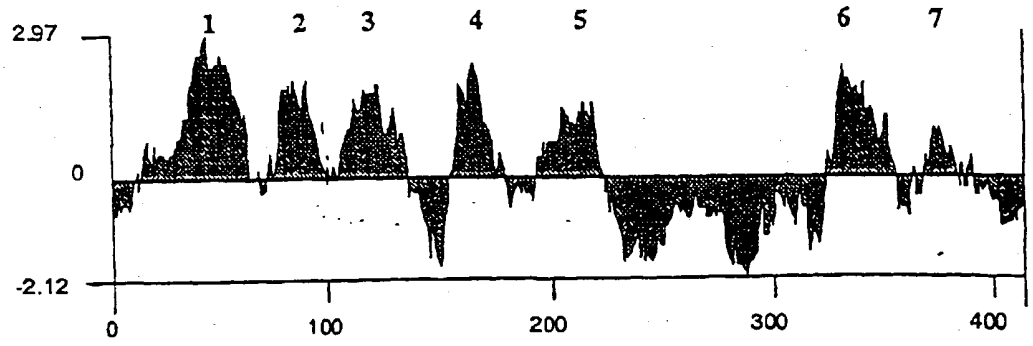

Figure 2

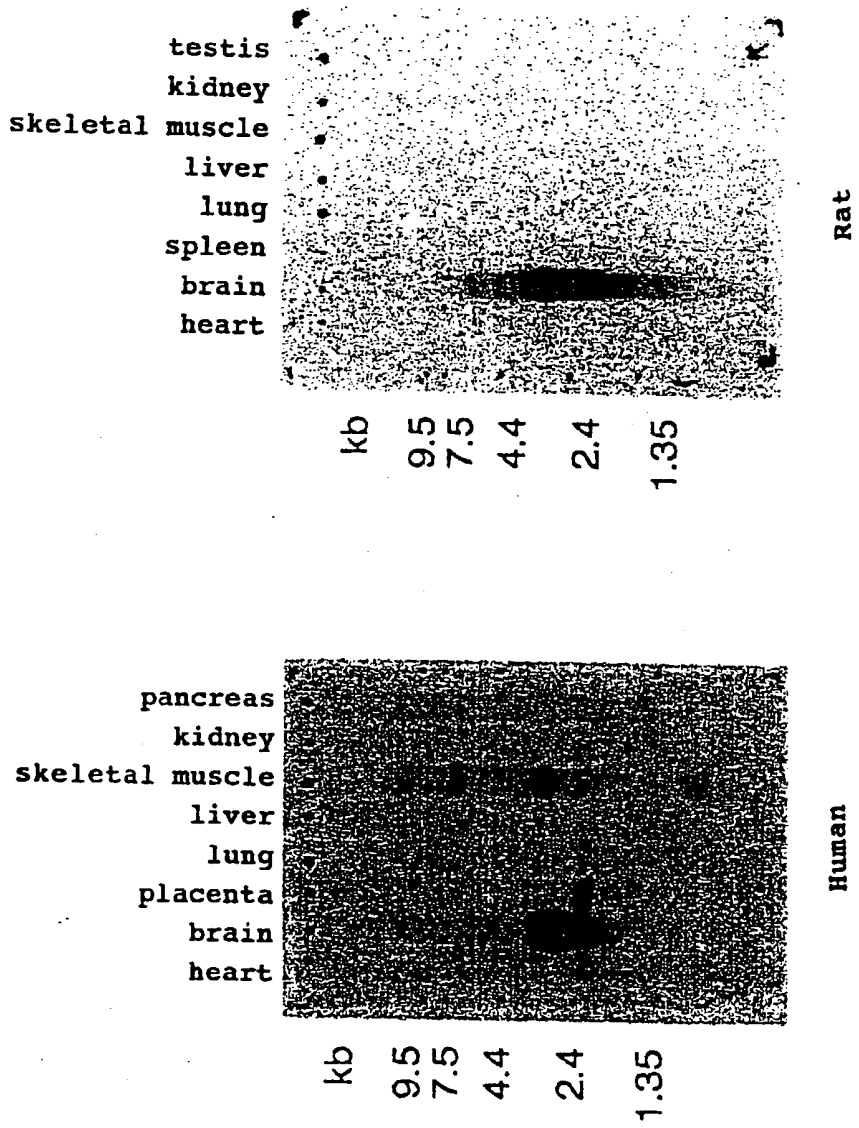
testis
kidney
skeletal muscle
liver
lung
spleen
brain
heart
kb
9.5
7.5
4.4
2.4
1.35
Rat
pancreas
kidney
skeletal muscle
liver
lung
placenta
brain
heart
kb
9.5
7.5
4.4
2.4
1.35
Human

Figure 3

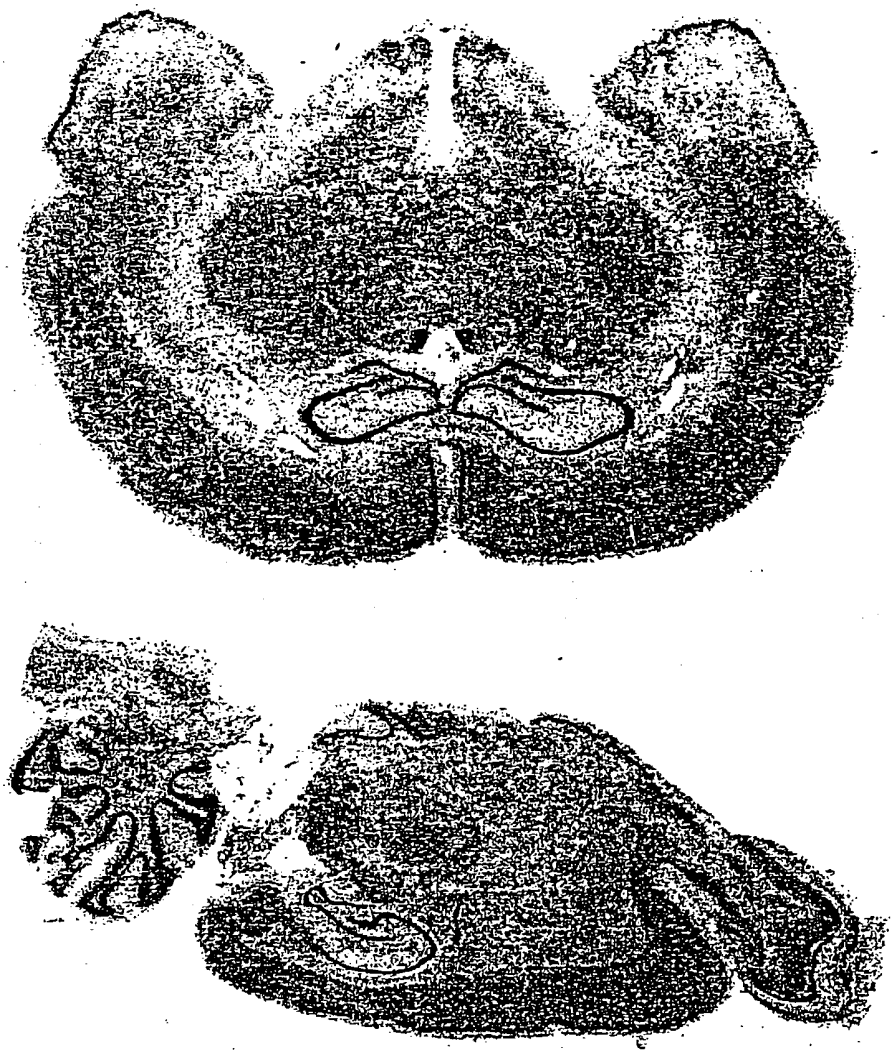

Figure 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/05967

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl⁶ C12N15/12, C12N15/63, C12Q1/02, C12P21/08, C07K14/705, C07K16/28, C12N1/21, C12N1/19, C12N5/12
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl⁶ C12N15/12, C12N15/63, C12Q1/02, C12P21/08, C07K14/705, C07K16/28, C12N1/21, C12N1/19, C12N5/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPI (DIALOG), BIOSIS (DIALOG), EMBL/DDBJ/GenBank/Geneseq

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Bonner, T.I. et al., "Identification of a Family of Muscarinic Acetylcholine Receptor Genes" Science (1987) Vol. 237 p.527-532	1, 3, 5-14
Y	Dewan, Z. et al., "Molecular characterization of a rat arufa2B-adrenergic receptor" Proc. Natl. Acad. Sci. USA (1990) Vol. 87, No. 8 p.3102-3106	1, 3, 5-14
Y	JP, 7-67654, A (Mitsubishi Kagaku Bio-Chemical Laboratories, Inc.), 14 March, 1995 (14. 03. 95) (Family: none)	2, 4, 5-14
Y	Ernest, G.P. et al., "Distinct primary structures, ligand-binding properties and tissue-specific expression of four human muscarinic acetylcholine receptors" The ENBO J. (1987) Vol. 6, No. 13 p.3923-3929	2, 4-14

[x] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier document but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
12 March, 1999 (12. 03. 99)	30 March, 1999 (30. 03. 99)
Name and mailing address of the ISA/ Japanese Patent Office	Authorized officer
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP98/05967

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	Thomas, B. et al., "A Novel Subtype of Muscarinic Receptor Identified by Homology Screening" Biochim. Biophys. Res. Commun. (1987) Vol. 149, No. 1 p.125-132	1-14
A	Maria, F.B. et al., "Normalization and Subtraction: Two Approaches to Facilitate Gene Discovery" Genome Res. (1996) Vol. 6, No. 9 p.791-806	1-14

Form PCT/ISA/210 (continuation of second sheet) (July 1992)